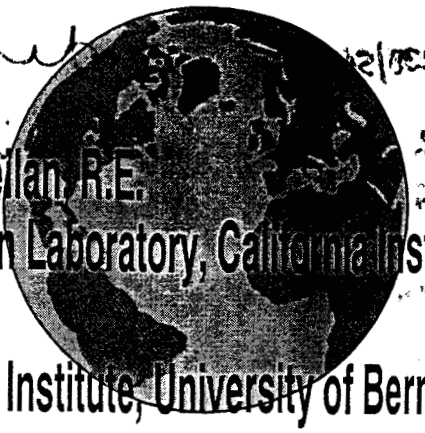
Breadth of Scientific Activities and Network Station Specifications in the IGS



Moore, A.W.; Neilan, R.E.
Jet Propulsion Laboratory, California Institute of Technology
Springer, T.A.
Astronomical Institute, University of Bern
Reigber, Ch.
GeoForschungZentrum Postdam

A Very Brief History of the IGS

- Approved activity of the International Association of Geodesy (IAG) with official start of service 1 Jan 1994. FAGS service since 1996.
- Mission: "To provide a service to support geodetic and geophysical research activities, through GPS data and data products."
- Network infrastructure and products were in large part originally commissioned for geodynamical investigations

Quality of the IGS Products

Products Delay	Predicted* Real Time	Rapid* 17 hours	Final 11 days	Units
Orbit	50.0	10.0	5.0	cm
Clock	150.0	0.5	0.3	ns
Pole		0.2	0.1	mas
LOD		30.0	20.0	μs/d
Stations			5.0	mm
Troposphere			1.0	mm PWV
Geocenter			30.0	mm
Terrestrial Scale			2.0	ppb

* 24-48 Hour prediction; AC's provide also 0-24 Hour predictions
* AC products available at 8:00 Hours UTC

IGS Working Groups and Pilot Projects

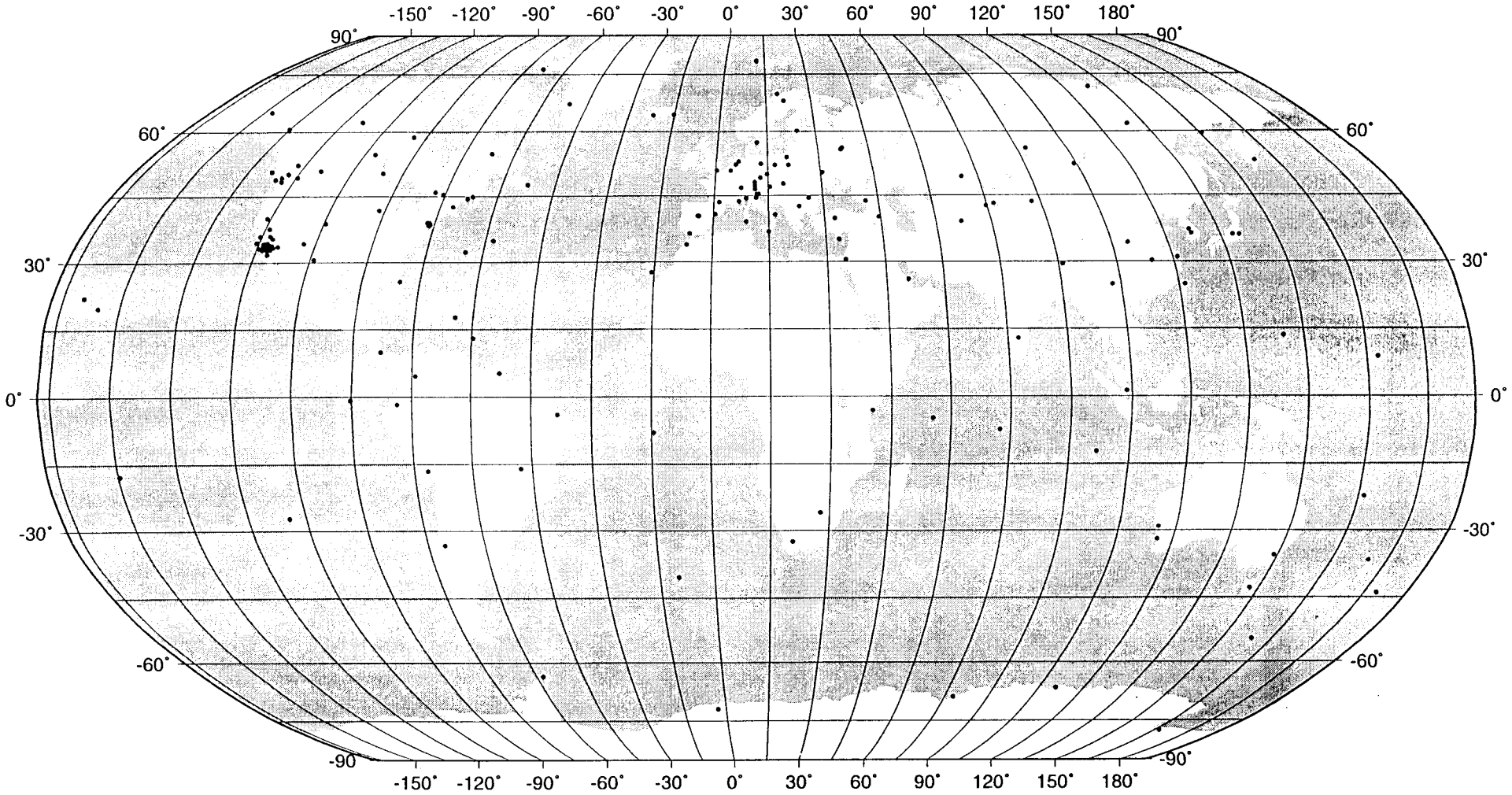
- A Working Group works on a paticular topic related to the IGS components according to goals and schedule specified in the working group's charter.
- A Pilot Project aims at the development of particular IGS product(s) or service(s) relying on the IGS infrastructure.
- Both established by the Governing Board
- Generally "new directions" come from a working group or pilot project.

Current Working Groups and Pilot Projects

- Reference Frame Coordination; R. Ferland
- IGS/BIPM Time Transfer Project; chairs J. Ray and G. Petit
- Ionosphere WG; chair J. Feltens
- Troposphere WG; chair Gerd Gendt
- International GLONASS experiment; chair P. Willis
- Low-Earth Orbiter WG; chair M. Watkins
- Tide Gauges, CGPS, and the IGS (seed activity); chair M. Bevis

GPS TRACKING NETWORK

International GPS Service



April 1999

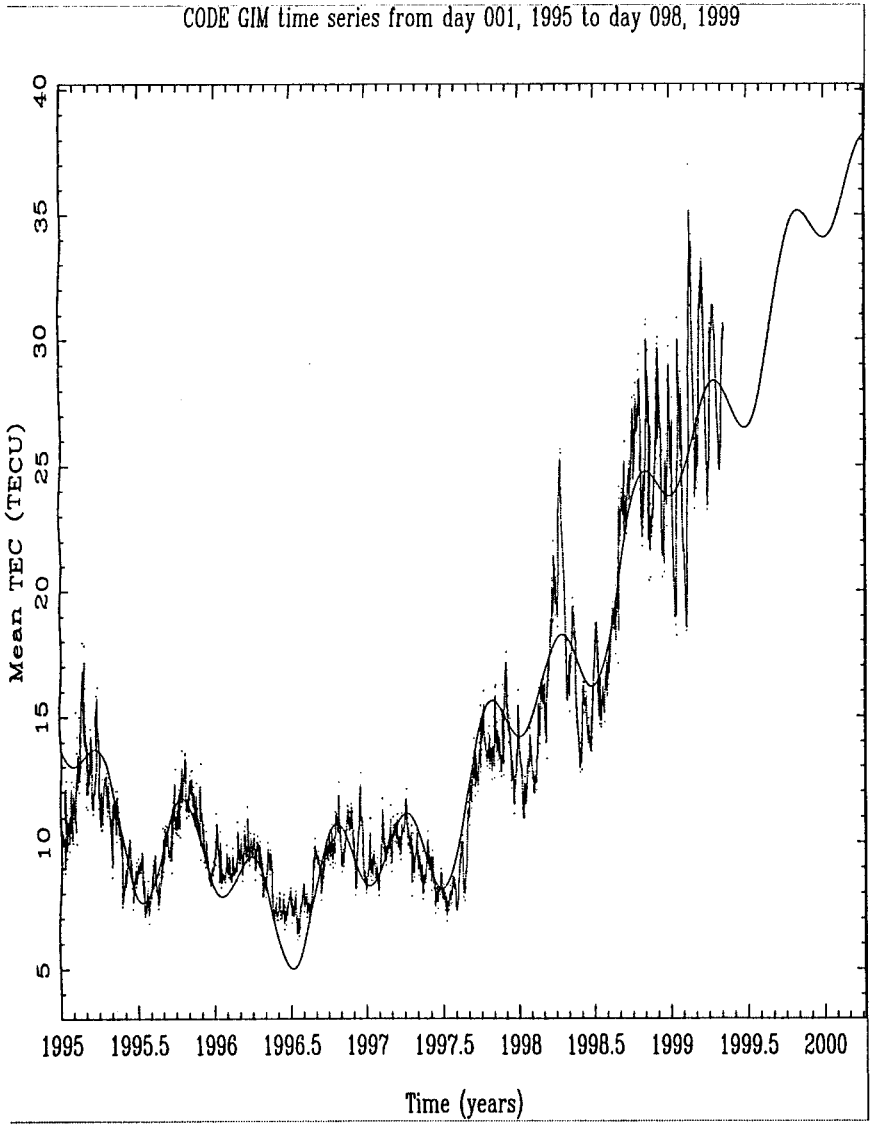
Carrying Out Project(s)

- May require specialized instrumentation
- May require specialized operating methodology
- Will require organization and guidance to participants

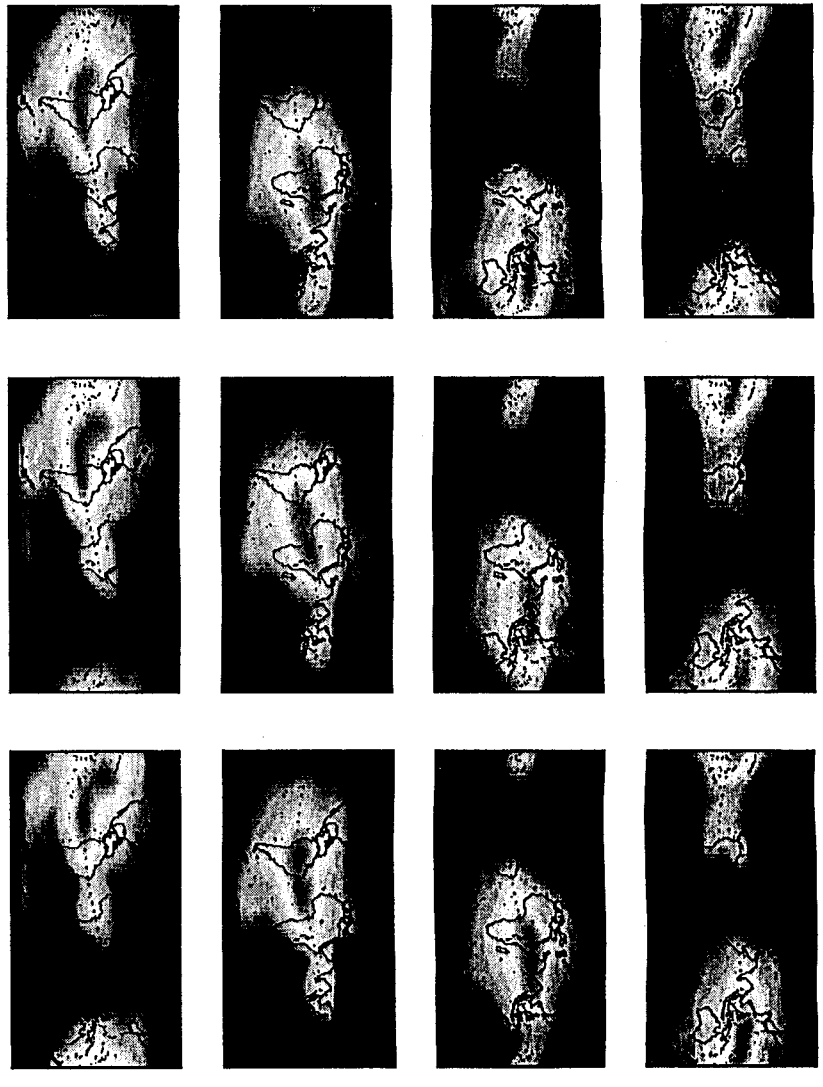
Network stations end up described as points in N-dimensional instrumentation & location space (!)

Ionosphere Working Group

- Formed 28 May, 1998
- Short-term goal of global ionosphere total electron content (TEC) maps with delay of about one week (realized)
- Only very preliminary comparison/combination at this time
- Long-term goal of near real-time or real-time TEC availability
- Implies global coverage of low latency stations


CODE GIM time series from day 001, 1995 to day 098, 1999
Mean TEC (TECU)
5
10
15
20
25
30
35
40
1995
1995.5
1996
1996.5
1997
1997.5
1998
1998.5
1999
1999.5
2000
Time (years)

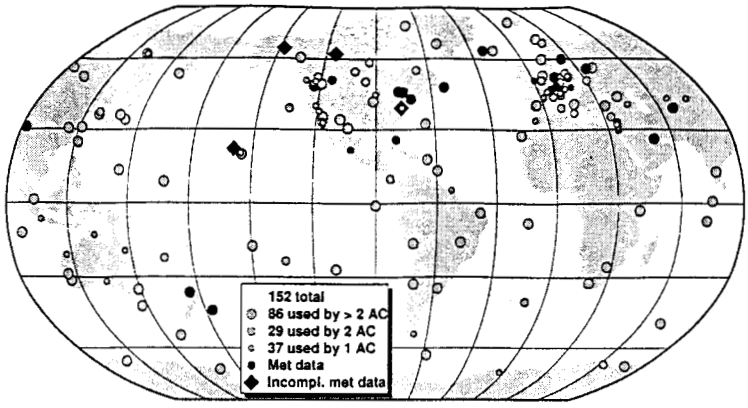
6



8

Troposphere Working Group

- Zenith neutral delay (ZND) estimates are a usual IGS product since 1997
- Approximately 80 sites analyzed by >2 ACs



Troposphere Working Group

- Precise meteorological sensors required for calculation of precipitable water vapor (PWV) from ZND. It is now recommended to install a precise barometer at all IGS sites.
- Met sensors number only 30 and so far, can be problematic (with respect to data dropouts, etc)
- Latency requirement not stringent at present due to low density of sites with met sensors

Tide Gauges, CGPS, and the IGS

- IGS has an advisory role in the deployment of continuous GPS stations at tide gauges
- Technical committee producing station standards document
- UH Pacific GPS Facility & Sea Level Center installing 3rd & 4th stations now
- Around 20 globally distributed stations forseen for the purpose of calibrating satellite altimeters

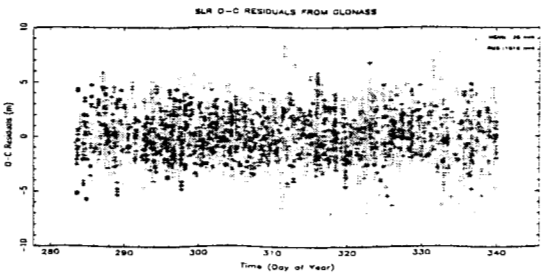
Tide Gauges, CGPS, and the IGS

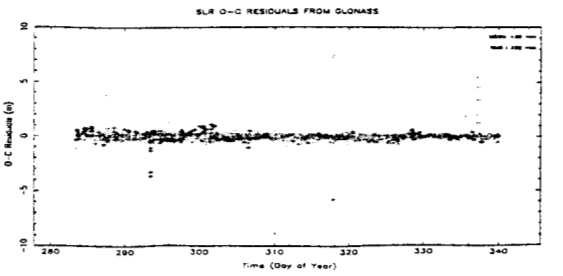
- Being co-located with tide gauges, these stations are often (geodetically speaking) poor in terms of stability
- Communications also poor; latency is not a concern, but delays of weeks to months for data delivery means "classic" IGS processing will not be performed

IGEX-98 (International GLONASS Experiment)

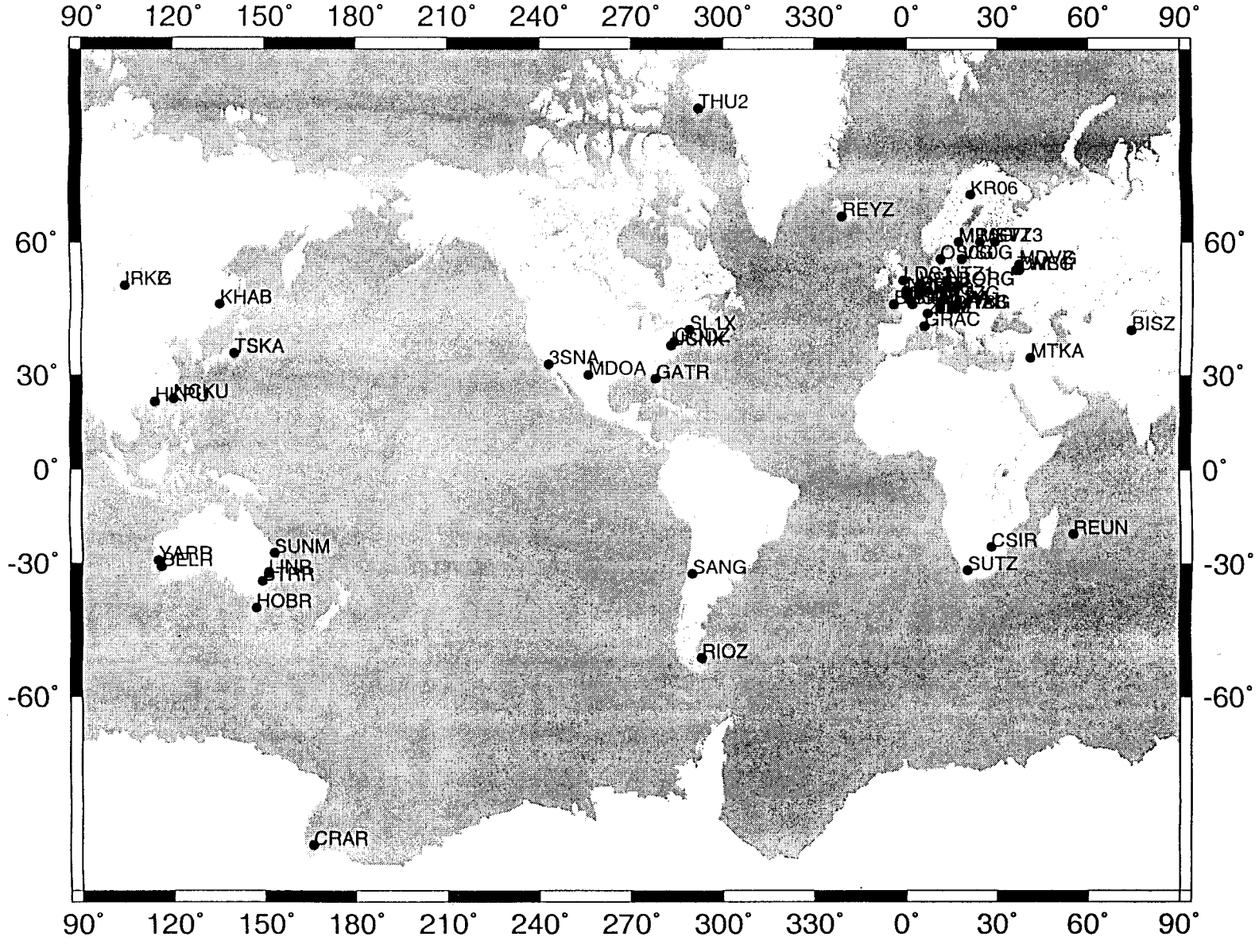
- Joint working group of CSTG, IGS, & ION, with IERS sponsorship. Oct 18-Apr 17.
- Motivations
  - No SA or AS on GLONASS
  - Combined system 41 satellites
- Objectives
  - Precise GLONASS orbits (1m or better)
  - evaluation of orbits by SLR
  - evaluate improvement of positioning capabilities over GPS alone
  - Compare PZ-90 with WGS84 and ITRF
- IGEX workshop before ION, Nashville, Sept.

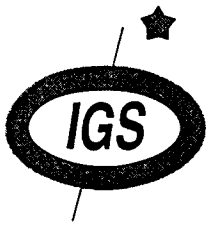
Broadcast GLONASS orbits compared to IGEX orbits





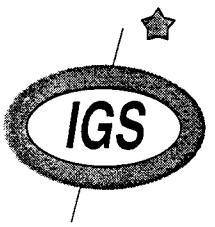
IGEX


90° 120° 150° 180° 210° 240° 270° 300° 330° 0° 30° 60° 90°
60°
30°
0°
-30°
-60°
THU2
KR06
REYZ
IRKZ
KHAB
TSKA
SL1X
3SNA
MDOA
GATR
MTKA
BISZ
SUNM
YARR
SANG
CSIR
REUN
SUTZ
HOBR
RIOZ
CRAR



IGS/BIPM Time Transfer Project

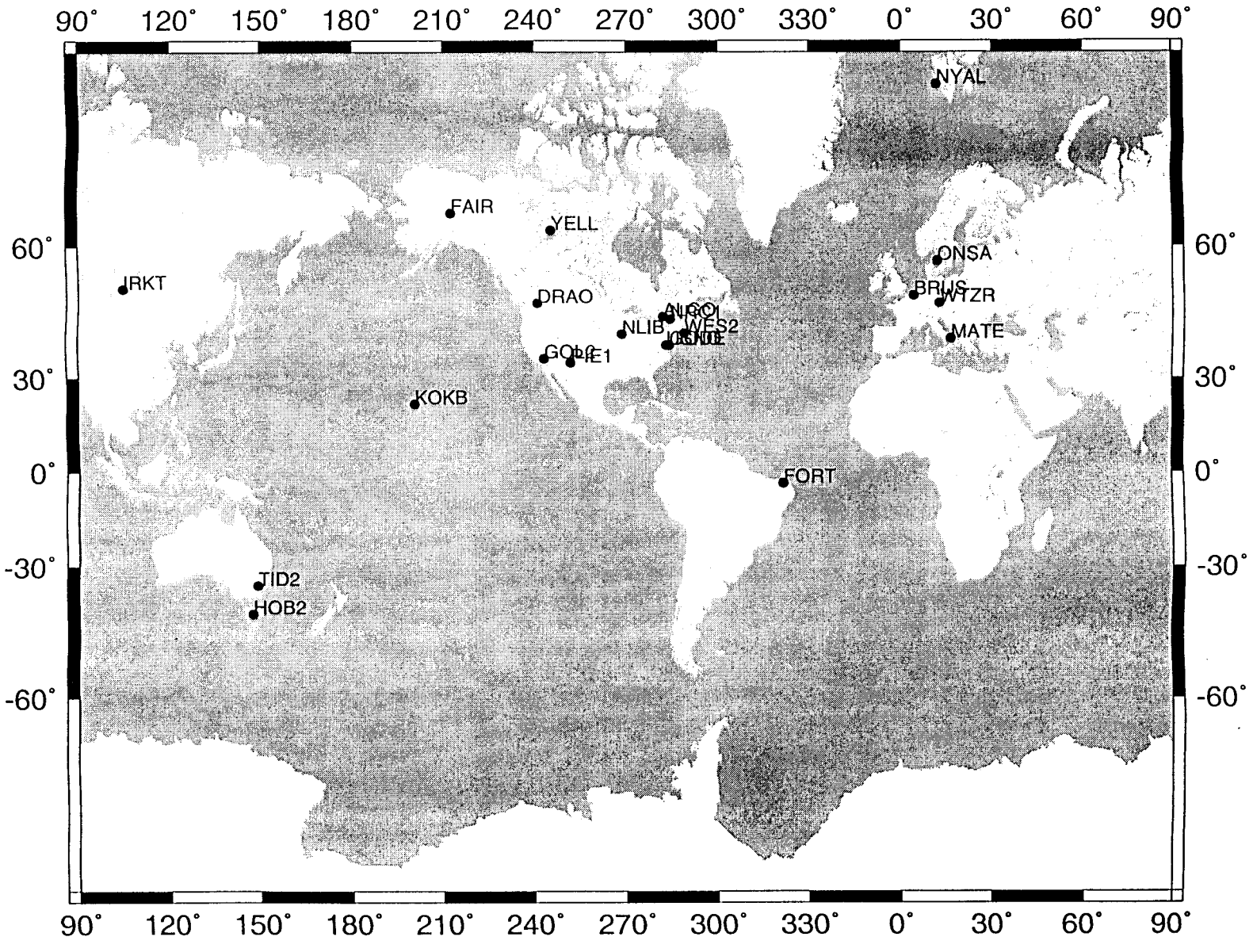
- Objectives
  - Exploit GPS pseudorange & carrier phase data to determing satellite & receiver clocks
  - Calibration measurements to provide access to UTC via external standards at timing labs
  - Global time & frequency transfer with potential accuracy <200ps
- Other long-distance time transfer techniques: comparisons at ns-level
- IGS stations located at timing laboratories (currently 11) enable improved maintenance of international atomic time scale



IGS/BIPM Time Transfer Project: Instrumentation

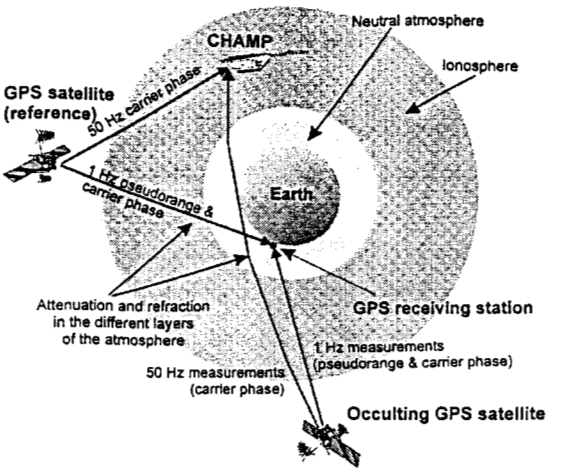
- Timing applications highly sensitive to delays
  - receiver
  - antenna
  - cable (!)
  - temperature effects on all of these
- Especially important for site changes to be promptly communicated to analysts

Fiducial clock



Working Group on Low Earth Orbiters

- Chartered to explore the role of LEOs in IGS
- Many LEO missions coming soon



(insert Ruth's LEO table)

DISREGARD
AWM

LEO Mission Matrix of Basic Characteristics*

~1200 OCCULTATIONS/DAY

Mission	Agency Processing Center	Sample Rate (SV)	Download Frequency* Occultation POD data/ Downlaod	Downlink Station Location	Daily Data Volume for Flight	Nominal Orbital Elements	Website or Further Information Notes
Oersted 2/99 14 mo.	Danish Meteorological Institute (DMI)	10 Hz	? 2.6 MB	Copenhagen, Aalborg,IKT (Denmark)	5.2 MB	h= 500- 850 km, elliptical polar orbit, i=~85°	http://gate.dmi.dk/fsweb/projects/oersted
Sunsat 2/99 ~5 years	Univ. of Stellenbosch Sth. Africa	50 Hz	2/day	Sth. Africa, Stellenbosch Univ.	20 MB	h=650- 820 km, elliptical polar orbit	http://sunsat.ee.sun.ac.za/index.html SLR retroreflectors
CHAMP 12/99 5 years	GFZ/DLR	0.1-50 Hz	2/day 10 MB	Neustrelitz, Germany	20 - 90 MB	h=470 km, i=87°	http://www.gfz-potsdam.de/pb1/CHAMP/champ.htm NADIR ANTENNA SLR retroreflectors
SAC-C 10/99 4 years	CONAE, Argentina	0.1-50 Hz	2/day 10 MB	Cordoba, Argentina	20 MB	h=707 km, quasi-polar circular, sun synch	http://www.conae.gov.ar/caratula.html link to SAC-C 4 ANTENNAE
ICESat/GLAS July 2001 3 years	NASA/EOS					h=600 km, circular 'frozen', i= 94°	http://www.csr.utexas.edu/glas/ http://icesat.gsfc.nasa.gov/ SLR retroreflectors
GRACE (2 sv's) June 2002 5 years	NASA/GFZ	0.1-50 Hz	2/day ~40 MB (10 MB/sv/pass)	Neustrelitz, Waldheim, Germany	~100 MB	h=500 km, i= 87°	http://www.csr.utexas.edu/grace/ SLR retroreflectors
COSMIC (ROCSAT-3) (~8svs) 2002 2 - 5years	National Space Program Office, ROC UCAR	100 Hz	every 100 min 5 MB/sv/pass	Taiwan, Fairbanks, Kiruna	~400-600MB	h=400 - 700 km sv stacking, i=75°	http://www.nspo.gov.tw/e30/welcome.html NSPO, COSMIC = ROCSAT-3 & http://www.gst.ucar.edu/ Includes COSMIC and GPSMet
GOCE 2003 - 2005 6-8 mo.	ESA/ESTEC					h=260 km, i=96.5 circular sun-synch	http://www.estec.esa.nl/vrwww/EXPLORER.html

4000 OCC. PER DAY

Not all fly the JPL developed receivers

JPL GPS flight receiver information: http://rogueweb.jpl.nasa.gov

* DOES NOT INCLUDE ALTIMETRY MISSIONS; TOPEX/POSEIDON, GPSMET, GFO, JASON, METOP, EUMETSAT, FEDSAT,..

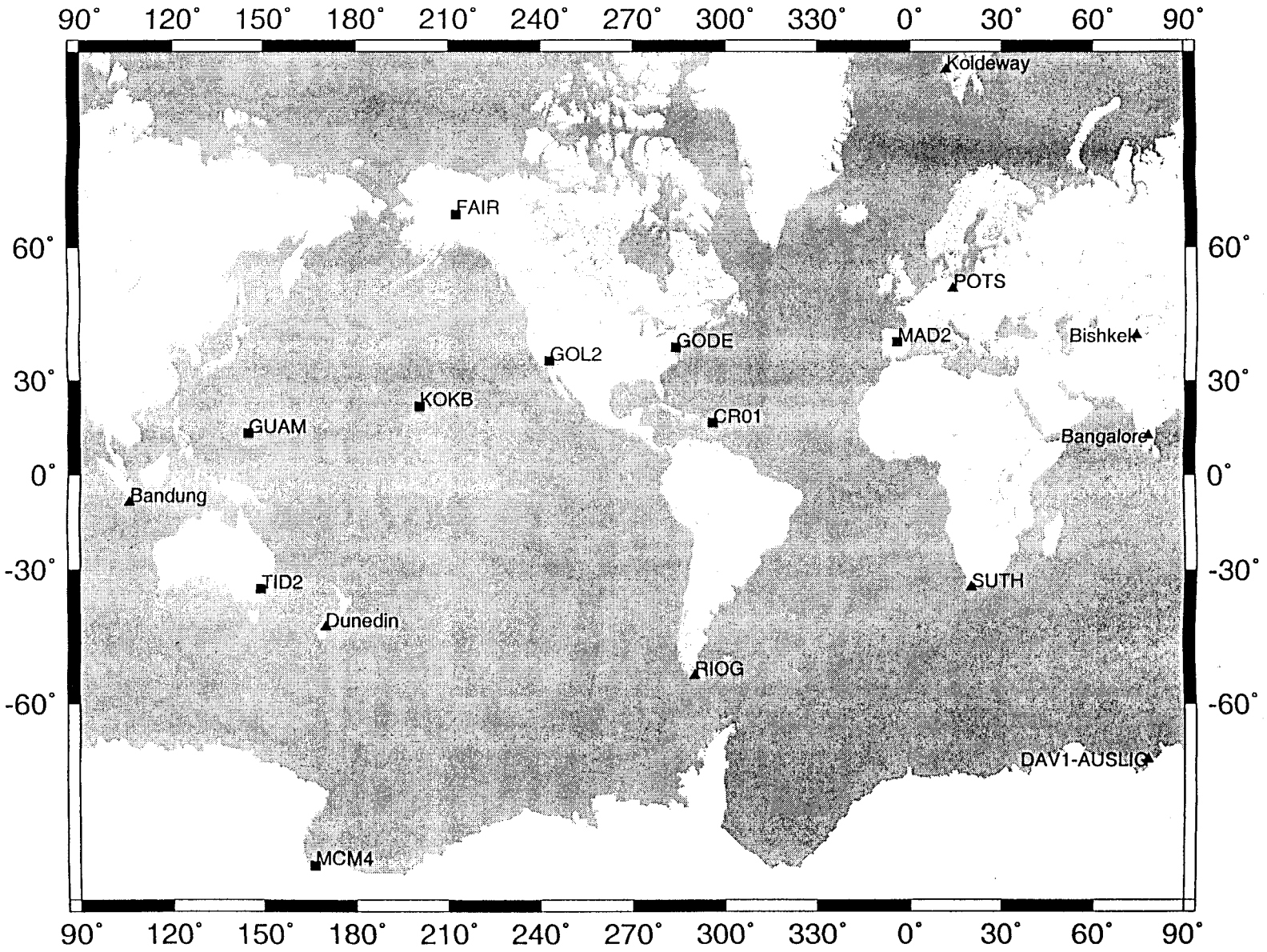
JPL/GFZ/IGS LEO Workshop March 1999, Potsdam

- Recommendation 1: committee to codify standards for ground stations
  - high-rate (1s) data
  - subhourly downloads
  - low latency => reliable, high bandwidth comm
  - track <20 degrees

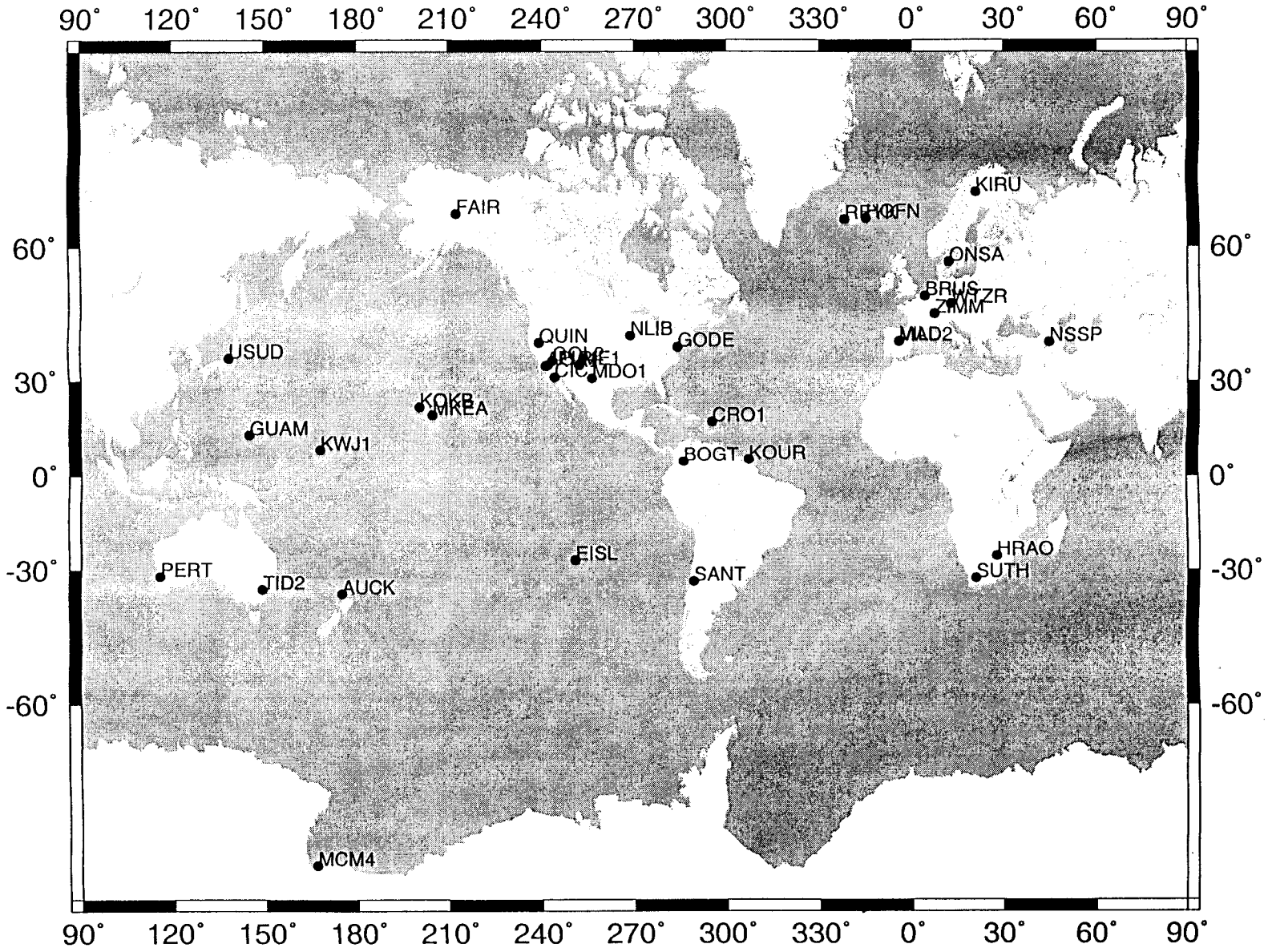
LEO Network Communications

- Global realization of low-latency and higher data-rate operation is necessary
- May be beneficial to utilize a common commercial solution for particularly remote areas
- Demonstration project for high-rate data communications with VSAT organized by UNAVCO

Proposed CHAMP Ground GPS Network



Hourly RINEX



LEO Workshop other recommendations

- Analysis centers to voluntarily demonstrate ultrarapid analysis product (orbit, clock, EOP, and predicts) with <3hr latency mid-99
- Exchange of larger volumes of LEO ground support data implies a binary format. Subcommittee formed.
- 3-6 month Pilot Project to begin 8/99 with 1Hz data in new binary format will evaluate impact of flight data in IGS products. Call for participation to be issued.

Wrap-up

- IGS moving quickly in multipurpose arenas
- Network coordination is challenging!
- IGS Central Bureau Information System http://igscb.jpl.nasa.gov
- Good summaries of projects in Annual Report & Network Workshop Proceedings (coming soon) online
- Thanks to all WG chairs